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## UPDATING A FILE IN A FRAGMENTED FILE SYSTEM

Inventor:

Christopher Spiegel

Prepared by:

BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP

32400 Wilshire Boulevard  
Los Angeles, CA 90025-1026  
(408) 720-8598

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SP#17 This application is related to U.S. Patent Application No. 09/675,578, entitled, "INCREASED RELIABILITY OF DATA STORED ON FLASH MEMORY IN APPLICATIONS SENSITIVE TO POWER-LOSS" filed on September 29, 2000, and U.S. Patent Application No. 09/063,954, entitled, "DYNAMIC ALLOCATION FOR EFFICIENT MANAGEMENT OF VARIABLE SIZED DATA WITHIN A NONVOLATILE MEMORY," filed on April 21, 1998.

**[0001]** The present invention relates generally to updating of computer memory storage systems. In particular, this invention is draw to reliably updating a file of a fragmented file system with changed data.

[0002] There are many devices that need to store information, such as data and code, in memory and other forms of nonvolatile storage, which need to periodically make updates. Such devices include, without limitation, a variety of computer systems, telecommunication devices, components of other devices, networking devices, memory cards, navigation devices, and the like.

[illegible]



is limited in devices that have data files comprising significant portions of the total storage available.

[0007] In general, the shortcomings of the currently available methods for modifying files are inadequate for providing reliable updates. In particular, previous methods require enough storage space for complete backups for the file(s) being updated.

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## BRIEF DESCRIPTION OF THE DRAWINGS

## DETAILED DESCRIPTION

[0015] The present invention provides for updating a file by making a backup copy of a portion of the file that includes changed data. Through cross-linking of certain storage areas, called units, the revised segment of the file is related to the other file portions.

[0016] In one embodiment of the updating procedure, the changed data may involve a replacement of some of the original data with new data via an overwriting procedure. In other circumstances, the changed data in a file may also include adding data to the file by appending new data onto existing data. Furthermore, the changed data may entail truncating a file portion. Usually, once the changed data has been created, the old data is deleted. According to these procedures, changed data may be easily included in a file in a manner that conserves storage space compared to prior procedures for reliable updating that require duplicating the entire file.

[0017] Moreover, the present invention permits tracking of the progress of an updating procedure by attaching various labels to the units that indicate the status of revisions being made to the unit. For example, a unit may be marked as a backup copy during the update and unmarked after the update is completed. If the procedure becomes interrupted, the label is used to determine whether to restore the original unit or to keep the current unit. Once the determination to delete a unit has been made, the unit may be marked as invalid and the unit space will become available for new units.

[0018] Various status labels may also assist in relating all portions together. A unit that has been newly formed may be labeled as unlinked to signify that the unit has not yet been linked to any parent data unit. Units may be marked as linked if the unit is related to portions of the file through cross-links with other units. A linked unit may transition through several states during the updating process, e.g. truncate, overwrite or discarding.

Where an updating procedure fails, the status labels may be used to determine the appropriate members of a storage system structure having proper data.

[0019] The storage system employing the methods of updating files according to the present invention may be any of a variety of storage means, such as flash memory, magnetic disk, a magneto-optical disk or other read/write storage medium used to hold code, a database, files, or other data. These storage systems listed are by way of example and are not intended to limit the choice of storage that are or may become available in the data storage field, as described herein.

[0020] The storage system is useful in numerous devices having data that may need to be updated. Such devices include a variety of computer systems, e.g. desktop computers, laptop computers, etc. The storage system may be used in telecommunication devices, e.g. digital cellular telephones, personal digital assistants, pagers, digital cameras, digital set-top boxes, other wireless devices, etc. Furthermore, some components of other devices may find the storage system convenient, e.g. embedded controllers. Other devices include networking devices, e.g. LAN switches; memory cards, e.g. PC cards; navigation devices, e.g. global positioning system receiver and base stations; and other such devices. The device includes a processor that may be directed to carry out the reliable updating processes as described herein, and according to the present invention.

[0021] The present invention uses a fragmented file structure, where a data object manages the multiple portions of a complete file. A data object is a data structure that uses sequence tables and data fragments to create data containers capable of holding non-contiguous data of any size. The base storage system has areas of memory called units that hold certain data related to the data object. A minimum amount of space that can be





sequentially read or written, even though the actual data fragments may be scattered randomly across the media. Typically, each sequence table consumes only a small amount of space in memory, e.g. 256 bytes, compared to the total amount of data contained within the data object.

[0025] In general, the units of the storage system may be arranged and related to each other in various fashions, such as a database format using look-up tables and/or handles to form a particular storage system structure. In one embodiment, these units are contained within blocks in the storage system, as illustrated in the exemplary storage system in **Figure 1**. The storage system **2** has multiple blocks **4** and **6** for storing different types of units **8**, including fragments **10** and sequence table units **12**. Each block may also include a block information structure that may include various information related to the block, such as an identification number for the block, the status of units contained within the block, and/or other information that assists in erasing a block. Where the storage system is flash memory, each of these blocks is individually erasable.

[0026] Along with the data in the units, there is certain header information associated with each unit to specify information related to the unit and data structure contained therein. Each of the information may be stored in separate fields or combined into one or more fields. For example, the information may include labels describing the unit as a backup copy, linked, invalid, discarding, valid and/or invalid, as well as specifying the unit's size and location within the media.

[0027] **Figure 2A** shows an example of unit headers **40**, **60** having a plurality of fields to identify and describe the unit. The unit header **40** has an ID field **42** into which a unique identifier for the unit is entered.

~~46~~  
~~60~~

Sub  
A3

~~66~~ denotes ~~68~~ mar

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replacement index (REPL INDEX) field **78** to provide a location for the replacement data along the line indicated by the replacement offset field **76**.

**[0033]** Some information within the replacement data **74** may assist the data object manager in mapping the portions of a data object. In the case where a handle to another unit is changed, such as by overwriting or truncating, the location of the original unit is stored in the original unit field **80**. For example, where the units are stored in blocks, the block having the original unit may be identified. Furthermore, the transition (TRAN) field **82** indicates whether the unit is in a transition state, such as overwrite or truncate. The valid replacement (VREP) field **84** denotes a valid replacement data and type field **86** is for presenting the type of replacement data.

[0034] A replacement data **88** may be also provided with an original unit header index field **90** rather than an original unit field **80**. This index field **90** may be referenced together with the value in the original unit field **80** to build a handle to the original unit, in instances that an updating procedure fails while in-progress.

**[0035]** The data object manager may utilize the various information in the unit headers and replacement data in relating the portions of the storage system structure of a data object before, during and after update. For example, when another unit contains a valid handle to a particular unit, the link value, e.g. in the link field **72**, is present in the unit header. Where there is no such link to another data structure, such as when a unit is newly created, an unlinked state may be indicated. During an update process, a linked unit may transition to a truncated or overwritten in TRAN field **82** or discarding state in discarding field **52**, indicating that the data in the previous unit (original unit) is no longer current and any handle referencing the previous unit needs to be updated to the new handle. To support the transitioning states, the unit may also contain information that

indicates the original handle of the linked unit. Once an update is complete, the original unit is marked as invalid, e.g. unlinked, and the unit having the current data is linked and valid. In this manner, the data object manager may recognize which units are appropriate members of the storage system structure comprising a data object.

[0036] The labeling of a unit's state is useful in case of an interruption, e.g. power outage, occurring during a file updating procedure. The device may determine whether a unit has been successfully updated based on the unit's label. If an updating has been disrupted, the data object manager may determine the state of the entire data object, and decide whether to delete all units in the storage system structure associated with the data object, restore a backup if one exists, or to complete the data object as much as possible even though the data object may not have the proper original or intended contents. However, data objects that are valid and properly linked together may be preserved since its content apparently contains correct data.

[0037] During an update process, whereby only the new portions of the total data object are updated until the update is complete. At the time of completion, the new data is merged into the original data object and only the original portions of the data that had been updated are invalidated, i.e. deleted.

[0038] Moreover, marking of a unit as a backup copy identifies a particular unit of a storage system structure being changed. In case of update failure, the unit(s) having data that may include partial changed data and partial old data is automatically deleted and the original data maintained. In this manner, the updating procedure according to the present invention is reliably performed.

[0039] **Figure 2B** shows an example of various entries 20, 22 that may comprise a sequence table. An array of any number of entries may be provided in a sequence table.

The order of the entries in the sequence table indicates the order in which the fragments must be assembled for completing the data object.

**[0040]** Entry **20** has a handle **24** to reference the location of a targeted unit, e.g. either a fragment or other sequence table unit. The current handle for a unit in a sequence table is maintained and may be changed when data is written.

**[0041]** Each consecutive valid handle entry in a sequence table may point to the unit that contains the next piece of data relating to the data object in the storage system structure. The handle may also have information on both the unit's location within a larger space in the handle index field **28**, e.g. the handle's physical offset within a block, as well as the identity of the space, e.g. block ID **26**. However, in some cases, the data object manager **14**, as shown in **Figure 1**, may be provided for searching through the data units, e.g. block information structure, to locate the desired fragment or fragments. The sequence table may have any number of handles so that one or more than one unit may be referenced by the sequence table.

**[0042]** Each entry in the sequence table may also contain other convenient information in one or more description field in addition to the handle. An entry may have a valid field **30** and invalid field **32** for indicating if the correctness of the data contained within the entry. A valid value in valid field **30** indicates that the entry has a handle with a proper handle for a target unit for locating target unit, whereas an invalid value in invalid field **32** denotes that a handle in that entry contains non-current and unusable handle information.

[0043] In some embodiments of a sequence table, there may be extra sequence table entries called replacement entries. These entries are used to supercede the current directory, without requiring the entire table to be rewritten. In embodiments with

replacement entries, the entry **20** may have a replaced field **34** for marking an entry as replaced. In this case, an index in the replacement index field **36** is valid or invalid.

[0044] One or more replacement entry 22 may be provided that are without current data and are available for writing data into it. Oftentimes, the number of handle entries and replacement entries that a sequence table may have is consistent for each sequence table of a storage structure. For example, half of a sequence table may be populated with handle entries, e.g. thirty-two (32) handles, and the remaining half, e.g. thirty-two (32) replacements, may be set aside for replacement entries.

[0045] Since existing entries may not be able to be rewritten in the storage system, the replacement entry **22** provides a means to update a handle's location without having to invalidate the entire sequence table. Moreover, the replacement entry permits handles to be changed without having to necessarily rewrite the entire sequence table or block. This entry updating process may conserve considerable time. Without the use of the replacement entries, an entire table or block may need to be erased in order to change a small pointer, e.g. 4 bytes.

**[00046]** Whenever an entry in a sequence table is to be rewritten, an available replacement entry is located and the new entry information is written into the replacement entry. The replacement index of the new entry is written into the original, i.e. previous entry in the chain of entries. The original entry is marked as “replaced” and a value is saved in the entry pointing it to the new entry. While the replacement entry is being written, the original entry maintains a valid status. After a new entry is completed, the status of the new entry is labeled as valid and the prior entry is invalid. In this manner all changes are tracked and may be referenced in case the update procedure fails while in process.





[0050] A chain of tables often starts with a single root table 106 ranked into the highest level and referencing units in a lower level. The root table 106 as shown is in level two and has two valid handles. Each of the handles references a unit e.g. sequence table unit in level two. In general, storage systems may have a single root sequence tables with one or more handles.

[0051] An intermediate sequence table 108 is ranked into a level that is lower than the root sequence table level, but higher than the level zero. This intermediate sequence table, shown in level one, points to either end sequence table(s) 110 in level zero or to other immediate sequence table(s) 108 in a next lower level. However, where a storage system involves only two levels of sequence tables, only a root sequence table and end sequence table unit(s) are present without any intermediate sequence tables.

[0052] A fragment is located by starting at the root sequence table unit 106 and following each handle in the immediate sequence tables 108 to the end sequence table unit 110. Usually each fragment has a chain of tables such that the entire data object may be reconstructed by reading all of the chains of sequence tables. A sequence table that points to a lower level unit, i.e. child unit, is often called the parent unit for the child unit.

[0053] The updating procedures may involve replacing data, i.e. overwriting, removing data, i.e. truncating or discarding, or adding data, i.e. amending. **Figure 4** is a flow chart showing one method of updating. A particular fragment that contains old data to be changed is identified **200**. The old data may be the entire contents of the fragment or only part of the data contained within the identified fragment.

**[0054]** A backup copy of the identified fragment having the old data is made and data is changed, e.g. changed data is inserted in replace of the old data **202**. Each sequence table in the chain for the identified fragment is read by starting with the root sequence table **204**. Thus, the valid handle in the entry that references the next sequential unit, i.e. fragment or sequence table unit, is read. Each of these sequence tables in the fragment's chain is duplicated to create backup versions, i.e. copy sequence tables, and these copies are stored **206**.

[0055] The chain of copied sequence tables are linked to each other, e.g. valid handles are written into an entry in the copied sequence table to reference the next copied sequence table in the chain 208. Thus, the new chain leads to the new fragment having the changed data rather than the old fragment with the old data. If any additional fragment is to be updated, the fragment is identified and the process repeats for this additional fragment until all fragments needing updated are manipulated according to the above-described procedure 210.

[0056] Valid handles for the copied sequence tables are written so that the copied sequence tables point to the appropriate original i.e. unaltered sequence tables and/or original fragments to complete the chains for the unaltered fragments **212**. The original sequence table(s) and fragment(s) that have been copied are deleted from storage **214**. The deletion may occur by various mechanisms. In one example of deletion, a fragment and sequence table may have their status modified from “valid” to “invalid.” Such invalid units may then be available for subsequent writing. Another way in which a deletion may occur is by marking a unit as a backup copy and often also in a transition state, e.g. truncate, overwrite or discarding. Where updating is not completed, the backup copies



[0060] In another alternative embodiment a storage system that has multiple levels of sequence tables, a method of updating a file may be used in which only each end sequence table that references the fragment(s) having the updated changed data is copied. An example of a storage system structure 250 employing this reliable updating method is shown in **Figure 3C**. Fragment 7 252 and Fragment 8 254 are identified as requiring updating and copied with the changed data as New Fragment 7 256 and New Fragment 8 258, respectively. A backup Copy End Sequence Table 1D 260 is created from End Sequence Table 1D 262 and the valid handle of Intermediate Sequence Table 2B 264 is written to reference the Copy End Sequence Table 1D 260. The original Fragment 7 252, Fragment 8 254, and End Sequence Table 1D 262 are all deleted.

[0061] As described above, the use of linking labels assists in maintaining a data object as fragment portions in a fault tolerant manner. **Figure 5A** shows a specific updating procedure to overwrite a fragment using link labels and overwrite transition state labels in a multi-level storage system. In this example, four fragments are linked together by three sequence tables in two levels 300. The overwriting begins in the second fragment, which is labeled as overwrite. The overwrite mark results in the link between the second fragment and its parent sequence table to become broken 302. The new location of the second fragment is written into its parent sequence table, causing the sequence table to be labeled as overwritten as well. Consequently, the link between this sequence table and the root table breaks 304. The link between the second fragment and its parent sequence table is reestablished and the second table is marked as linked again 306. This sequence table (now the child sequence table to the parent root sequence table) is reconnected to the root table by updating the root and resulting in the root sequence







